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Effects of Population Density on Water Quality in Calabar Municipality Cross River State, Nigeria

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Abstract

The study was carried out with the aim of assessing the effects of population density on groundwater quality in the area. A total of six (6) groundwater sample were collected from six (6) boreholes in the study area for analysis of their physic-chemical parameters. The results show the following range and mean value; temperature (28.5-30°C) with a mean value of 29.5°C, pH (6.0- 6.3) with a mean value of 6.05, indicating that groundwater in the area is slightly acidic, Electrical conductivity (95.2-296IJS/cm) with a mean value of 171.1IJS/cm, Total dissolved solid (47.6-148mg/l) with an average value of 85.4mg/l, Ca (0.8-1.8mg/l) with a mean value of 1.1 mgll, Mg (0.29 and 0.58 mgll) with a mean value of 0.4mgll, S04 (0-8 mgll) with a mean value of 3.2mgll, $N0_3$(0-6.1 mgll) with a mean value of 4.2mg/l, CI (6-10 mgll) with a mean value of 7.8mg/l and Faecal coliform (0-19 CFU/100) with a mean value of 8.8CFU/1 00. The distribution pattern of the chemical parameters does not show a clear relationship between population density and water chemistry. Finally, assessment of the water quality shows that groundwater in the study area is suitable for irrigation while groundwater around Ediba, Essien Town, Ikot Omin and Ikot Effanga is not fit for drinking, due to high content of coliform bacteria. Therefore groundwater in these areas should be treated before drinking.

Keywords: Population, density, water quality, and effects.

1. Introduction

Water is one of the most vital natural resources necessary for the existence of life. Of all natural resources, water is the most essential. It is fundamental to all vital processes of value to mankind. It seems abundant at first sight-almost 70 percent of the earth's surface is covered with water. Yet, perhaps, two billion people live in areas with chronic water shortages. Quantitative supply and water quality problems are mounting and could constrain economic development and human well-being in general. In other words, water can no longer be taken for granted: "Ensuring that present and future generations will have adequate food and water, and concurrent maintenance of the resource base on the environment are two of the most challenging tasks that have ever faced mankind"(Asuquo & Etim, 2012b).

Water quality is affected by population density of an area. However certain factors determine the population density of an area. Such factors are; relief- where the area is lowland, which is flat, population, tends to be high since it is possible for people to build on low lands. Whereas, highlands with mountain usually have low population due to the fact that it is usually difficult to build on mountains, Areas with dense resources tend to be densely populated while areas with sparse resources are sparsely populated. Areas with temperate climate tend to be densely populated as there is enough rain and heat to grow crops while areas with extreme climate is sparsely populated. Others are; areas with stable government, such as Singapore densely populated while those with unstable government like Afghanistan are sparsely populated, Good job opportunities encourage higher population, while limited job opportunities lead to low population, example Amazon rain forest.

Populations require water for domestic and municipal use; as an input in productive activities: agriculture, industry (including energy production) and service activities; and finally, in the evacuation of effluents (sanitation, removing industrial wastes etc.). Demand from all these sectors is mounting and competing with one another. To understand the nature of resource use issues in this area, it is necessary to keep in mind some characteristics of water supply. First of all, the seeming abundance of water is misleading. Freshwater, the only usable kind as far as human needs are concerned, is only a fraction of 2.5 percent of the water presents on our planet. Furthermore, most of the available freshwater is in the form of groundwater which, given its life cycle of several thousand years, must be regarded as unrenewable on a human time scale. In the end, only O.3percent of freshwater is renewable. Runoff, however, easily compares with human needs at the global level. But "usable flow is substantially less than runoff (Etim etal, 2012).

Water is irregularly spread over space and often is not found where it is needed. It is also irregularly spread over time. Time constraints on water use are strong especially, for domestic uses and industry that means supplies per person drop as population grows". These natural conditions set absolute limits to human use: "Human innovative talents can make the best possible use of the water that passes through a country, but technology cannot influence the rate at which water is naturally renewed from the global water circulation system". Water therefore is a finite resource: "The water cycle makes available only so much each year in a given location. Water is mobile and necessitate catchment, transportation and storage, with related costs and efficiency problems. Ultimately water availability can be regarded as a function of the costs of delivering water at the required place and time, rather than as a physical parameter. But those costs can be high and consumers usually are reluctant to bear them because of age-old perceptions of water as a free good (Edet, 1998; Kennth & Edirin, 2014).

Water resources are vulnerable, meaning that their flow patterns and chemical properties can easily be altered by human activities and natural factors in ways which negatively affect subsequent human usages. For instance, in Calabar municipality, waste are generated and discarded without treatment and with little or no form of control. These wastes find their way to groundwater through percolation, which results in the alteration of the water quality. Quality considerations are important whatever the utilization of water: industrial, agricultural and domestic usages all have their criteria of adequacy (particularly strict ones in the latter case) (Ezenwa, 2014).

It is a well-established fact that man's survival on planet earth absolutely depends on the environment (air, water and land). Therefore, unhealthy environment leads to unhealthy human existence. The quality of our environment is usually altered by our own activities such as; urbanization, industrialization and agriculture. These activities produce wastes which are dumped into the environment, resulting in the alteration of the physical, chemical and biological properties of the environment. In the study area (Calabar Municipality), there is an increase in human activities due to population increase. Since the increase in human activities will lead to increase in the volume of waste generated which will result to been dumped, then more waste will be dumped into the environment leading to higher environmental contamination. Boreholes which are located near waste dumps, latrines or soak away pit are likely to be contaminated by materials from these places (Ekwuemo, 2010; Eni et al, 2011).

Contaminated water has been reported to cause health problems such as Cholera, Typhoid, dysentery, diarrhoea etc. Calabar municipality happens to be urban area with high population depending on water, water is a basic component of life, and its quantity and quality vary over time and space. At present, private borehole operators sell untreated water to members of the teeming population in this area and so there is no quality standard that has been established in this area. The current upsurge in the incidence of water-borne disease most especially typhoid and diarrhoea is related to this ugly development (Okezie, 1989; Abimbola et al, 2008)

As the population of the area has been on the increase because of the peaceful atmosphere of the area, industrialization, tourism, activities, better health care to reside and work in this area, so the need for portable drinking water and domestic activities is on the increase and there is pressure on water and increase in construction of boreholes. This issue of continuous abstraction of the groundwater map is another major problem in the area to the extent that anybody anywhere in the area sink borehole without regulation or control pose a great danger to ground water with respect to exhausting and contamination (Eze and abua, 2003). With regards to water demand in the area, no attempt has been made to compute the water demand in the area even though the populations of the area has been increasing at an alarming rate, leading to indiscriminate sinking of boreholes, without standard leading to contamination, hence there is the problem of quality (Adekunle et al, 2007; Fidelis et al, 2012).

The present network of work of work pipes in this area is grossly inadequate, most of these pipes have become odoriferous colourful, tasty and undrinkable, and most homes do not have water supply, cisterns and therefore rely on public standpipes and private boreholes for water supply, leading to water management crisis in this area. It is against these limitations upon which these studies are to be contemplated (asuquo & Etim, 2012 a)

The aim of the study is to examine the effects of population density on water quality in Calabar Municipality, in order to achieve this, the following specific objectives will be considered;

- To examine the physio-chemical characteristics of groundwater (boreholes) in the area.
- To assess the pollution status of groundwater (boreholes) in the area by comparing their physico-chemical parameters with that of the world Health Organization, WHO (2004) permissible limits.
- To establish the distribution pattern of measured parameters of groundwater in the study area.
- To examine the effect of population on water quality status.

2. The Study Area

2.1 *Location and Extent*

The area (Calabar municipality and its environs) lies between latitudes 4°40' and 5°05' N of the Equator and longitudes 8°35' and 8°50' E of the Greenwich Meridian. It covers a total land area of about 331.551Km^2. Accessibility of the area can be through the major road Murtala Mohammed Highway (Fig.1). Various untarred roads also lead to sample locations.

The study area lies within the sub-equatorial south climate belt which is roughly characterized hy four (4) seasons vrz; the long wet season (March to late July), the short dry season or August break (Early to late August), the short wet season (September to October) and the long dry season (November to early March) (lIoeje, 1991). Annual rainfall is reasonably high, with temperature range between 25 - 28°C (lIoeje, 1991). The area is characterised by a double maxima of rainfall which occur in the month of June and September. The high rainfall and heat favours high population density which in turn affect water quality in the area.

The vegetation of Calabar Municipality is described as the lowland rainforest (Iloeje 1991), consisting of trees, shrubs and grasses. There are also plantains, fallow bushes and forest reserves. The presence of tall trees encourages lumbering and the lowland favours the building of houses leading to increase in population. As population increases, so do human activities affect groundwater quality in Calabar Municipality thus making this area attractive for research.

In most cases, water that is good enough for domestic usage is judged to be unsuitable for other purposes. Therefore, in this study, emphasis is placed mainly on the domestic suitability or the portability of the water in the study area.

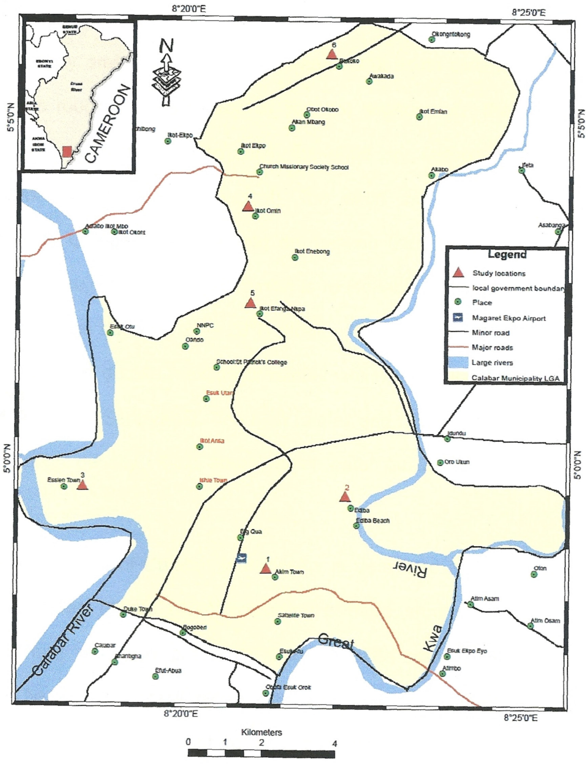
3. Materials and Methods

The procedure and strategies used in obtaining the data the data for the study. The researcher took the following pattern, sampling techniques, experimental procedures, and determination of parameters, materials and method used. A total of six (6) groundwater samples were collected from six (6) boreholes in the locations shown in fig 1. The sample locations were chosen based on their population figure of 1991, published by the National Population Commission. The water samples were collected into pre-washed 1 litre polyethylene bottles. The bottles were rinsed with the water from the borehole in which the sample was to be collected. Prior to the collection of the water sample, the well was allowed to pump for about 5 minutes to ensure stability before samples were collected. The water samples were then taken to Cross River State Rural Water Supply and Sanitation Agency (RUWATSSA) Laboratory for analysis.

In the field, the co-ordinates of the various sampling locations were determined using a GPS device. The most common method to determine latitude and longitude of a location is using GPS (Global positioning system) device to electronically record the co-ordinates. The GPS readings were appropriately read from the device and recorded in the various locations as shown in Table 1.

Table 1. Location, Co-ordinate and population figure of the study area.

Location	**Name**	**Co-ordinator**		**Population Figure (1991)**
		Longitude (E)	**Latitude (N)**	
W1	Akim	8^{0}21’13.473’’	4^{0}58’23.564’’	34,688
W2	Ediba	8^{0}22’22.845’’	4^{0}58’23.564’’	20,803
W3	Essien Town	8^{0}18’31.058’’	4^{0}59’28.412’’	6,421
W4	Ikot Effanga Mkpa	8^{0}20’54.353’’	5^{0}3’43.263	7,872
W5		8^{0}20’56.854’’	5^{0}2’18.236	2,747
W6	Bacoco	8^{0}22’66.875’’	5^{0}5’57.054’’	489



Map of Calabar Municipality showing sample locations

FIG.1: The Study Area Showing Sample Locations

4. Laboratory Procedure

(1) TEMPERATURE

This was determined with the thermometer. The thermometer was inserted into the water sample in a beaker and the reading was noted.

(2) pH

The pH was determined with a pH meter (model: Mettler Toledo MP 220). The pH meter probe was inserted into the water sample in a beaker, the READ key was pressed and the pH reading was taken.

(3) COLOUR

Colour was determined using LOVIBOND COMPARATOR. The test kit was assembled and the water sample was filled into a test tube and placed in the right hand corner of the comparator. The disc was placed on the comparator and rotated till the nearest colour match was observed; the value for colour was noted and recorded.

(4) TURBIDITY

A turbidity meter (Model: HANNA INSTRUMENT H193703) was used. The sample was placed in the turbidimeter bottle and the bottle wiped clean with a cloth to erase any. finger print that may affect the reading. The bottle was then placed on the turbidimeter and the READ key pressed, the turbidity reading was displayed.

(5) CONDUCTIVITY

Conductivity meter (Model: HANNA INSTRUMENT H18733) was used. The conductivity meter probe was rinsed with distilled water and inserted into the sample in a beaker, the conductivity reading was displayed.

(6) DISSOLVED OXYGEN

Method: Spectrophotometry

Procedure: A reaction cell was filled to over flowing and one (1) glass bead was added into it. O.Sml of Oxygen reagent O_2-1 K was added. Another 0.5ml of Oxygen reagent 02-2k was also added and mixed for 10 seconds. Lastly, 1 ml of oxygen reagent 02-3k was added, mixed and allowed to stand for 5 minutes. The dissolved oxygen value was then read out in the spectrophotometer at a wavelength of 489nm.

(7) CALCIUM
Method: Spectrophotometry
Procedure: 0.1 ml of the sample was placed in a test tube using pipette and 0.5ml of calcium reagent Ca-1 was added and mixed. O.4ml each of calcium reagent Ca-2 and Ca-3 were also added to the test tube and mixed. The sample was allowed to stand for 8minutes sto elicit full colour development and then filled into a reaction cell, placed in the spectrophotometer where the calcium concentration was displayed.

(8) MAGNESIUM:
Method: Spectrophotometry
1 ml of the sample was placed in a reaction cell and mixed and 1 ml of magnesium reagent Mg-1 k added to it. This was avowed to stand for 3 minutes and thereafter, 0.3ml of magnesium reagent Mg-2k added, mixed and placed in the spectrophotometer. Magnesium concentration was read at a wavelength of 568nm.

(9) TOTAL HARDNESS
Method: Spectrophotometry
1 ml of the sample was placed in a reaction cell and 1 ml of total hardness reagent H-1 k added with a pipette. 3 minutes reaction time was allowed before total hardness was determined in the spectrophotometer at a wavelength of 450nm.

(10) ALKALINITY
Method: Titrimetry
The sample was placed up to the 5ml mark in the test tube and 1 drop of methyl red indicator was added to it. The sample turns blue and a dropwise titration was carried out using reagent TL AL7 until there was a colour change. The value in the syringe was taken as the alkalinity value for the sample.

(11) NITRATE
Method: Spectrophotometry
1 microspoonful of nitrate reagent $N0_3$-1A was placed in a dry test tube and 5ml of nitrate reagent $N0_3$-2A added into it and mixed to dissolve. 1.5ml of the sample was added slowly and shaken. This was allowed to stand for 10minutes and nitrate concentration was read out from the spectrophotometer at a wavelength of 520nm.
(12) NITRITE
Method: Spectrophotometry
5ml of the water sample was placed in test tube and 1 microspoonful of nitrite reagent $N0_2$-AN was added and shaken to dissolve. A time of 10 minutes was allowed before reading out the nitrite concentration in the sample.

(13) AMMONIUM
Method: Spectrophotometry
5ml of the water sample was placed in a test tube and O.6ml of ammonium reagent NH_4-1 was added using a syringe. 1 level microspoonful of ammonium reagent NH_4-2 was also added, shaken and allowed to stand for 5 minutes. Ammonium concentration was determined at a wavelength of 520nm in the spectrophotometer.

(14) MANGANESE
Method: Spectrophotometry
5ml of the water sample was placed in a test tube and 4 drops of manganese reagent Mn-1 was added and shaken. This was allowed to stand for 2 minutes. Thereafter, O.2ml each of manganese reagents Mn-2 and Mn-3 were added, shaken and allowed to stand for another 2 minutes before reading the manganese concentration from the spectrophotometer at a wavelength of 520nm.

(15) IRON
Method: Spectrophotometry
5ml of the water sample was placed in a test tube and O.3ml of iron reagent Fe-1 was added, shaken and allowed to stand for 3 minutes. The iron concentration was then determined at a wavelength of 420nm in the spectrophotometer.

(16) SULPHATE
Method: Spectrophotometry
2.5ml of the water sample was placed in a test tube and O.2ml of sulphate reagent S04-1A added and mixed. 1 level spoonful of sulphate reagent S04-2A powder was added and mixed. The solution was then tempered in a water bath at 40°C for 5 minutes. 2.5ml of sulphate reagent S04-3A was added, mixed and the solution filtered

using Whatman No. 1 filter paper. O.4ml of sulphate reagent S04-4A was then added to the filtrate and mixed. The solution was again tempered in a water bath for 7 minutes at 40°C. This was transferred into a round cell and placed in the spectrophotometer to read off the concentration of sulphate in the water sample. Awavelength of 520nm was used.

(17) FLUORIDE
Method: Spectrophotometry
5ml of the water sample was placed in a reaction cell and 1 dose of fluoride reagent F-1 K powder was added, shaken and the fluoride concentration determined at a wavelenght of 620nm using the spectrophotometer.

(18) CHLORIDE
Method: Spectrophotometry
5ml of the water sample was placed in a test tube and 2.5ml of chloride reagent CI-1 was added and mixed. Chloride reagent CI-2 was also added, shaken and allowed to stand for 1 minute before reading out the chloride concentration from the spectrophotometer at a wavelength of 460nm.

(19) POTASSIUM
Method: Spectrophotometry
2ml of the water sample was placed in a reaction cell and mixed. O.6ml of potassium reagent K-1k was added and mixed, 1 level microspoonful of potassium reagent K-2k also added, mixed and allowed to stand for 5 minutes. The concentration of potassium was read out from the spectrophotometer at a wavelength of 690nm.

(20) LEAD
Method: Spectrophotometry
5ml of the water sample was placed in a reaction cell and O.5ml of Lead reagent Pb-1 k was added and mixed. The concentration of lead was determined in the spectrophotometer at a wavelength of 620nm.

(21) PHOSPHATE/PHOSPHORUS
Method: Spectrophotometry
5ml of the water sample was placed in a test tube and O.Sml of the phosphate reagent $P0_4$-1A added to it and mixed. This was followed by the addition of 1 level spoonful of phosphate reagent $P0_4$-2A. 5 minutes reaction time was allowed before reading out the phosphate concentration at a wavelength of 420nm.

(22) SODIUM
Method: Spectrophotometry
O.5ml of sodium reagent Na-1 k was placed in a reaction cell and O.Sml of the water sample added to it and mixed. A reaction time of 1 minute was allowed before reading the concentration of sodium from the spectrophotometer.

(23) ZINC
Method: Spectrophotometry
10ml of the water sample was placed in a glass vessel and 1 microspoonful of zinc reagent Zn-1k was added and shaken to dissolve (this is the pretreated sample). O.Sml of zinc reagent Zn- 2k was placed in a reaction cell and 2.0ml of the pretreated water sample added to it and mixed. O.Sml of zinc reagent Zn-3k was also added into the reaction cell and mixed. Zinc concentration was then determined in the spectrophotometer.

(24) COPPER
Method: Spectrophotometry
5ml of the water sample was placed in a reaction cell and O.5ml of copper reagent Cu-1 k was added and mixed. 5minutes reaction time was allowed before copper concentration was determined.

5. Results and Discussion

The result of physical parameters measured for groundwater samples taken from the study area is presented in Table 2. The Table shows that temperature ranges between 28.5 and 30°C with a mean value of 29.5°C. These values represent the ambient condition of temperature (Nganje et al, 2010). The Table also shows that pH varies between 6.0 and 6.3 with an average of 6.05, indicating that groundwater in the area is slightly acidic. Electrical conductivity ranges between 95.2 and *296pS/cm* with a mean value of *171.1pS/cm.* These low electrical conductivity values show low mineralization in the groundwater (Nganje et ai, 2010). Total dissolved solid varies between 47.6 and 148mgll with an average value of 85.4mgll.

Comparing the EC and TDS amongst the various locations where the groundwater was taken shows that these parameters where lower in samples collected from Ikot Effanga and Bacoco where population is smaller (Figures 2 and 3). Indicating that population may have some influence on water chemistry in the area.

Table 2. Physical parameters

Parameter	Unit	W1	W2	W3	W4	W5	W6	Min	Max	Mean	WHO
Temp	C^0	30.0	29.8	28.7	28.8	28.5	30.1	28.5	30.0	29.5	Ambi-ent
pH		6.0	6.3	6.0	6.0	6.0	6.0	6.0	6.3	6.05	6.5-8.5
Colour	Pt-Co	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	NG
Turbidity	FTU	3.0	1.0	1.0	0.0	0.0	0.0	0.0	3.0	0.83	NG
EC	µS/cm	97.7	121.9	296	217	199	95.2	95.2	296	171.1	500
TSS	mg/l	0.0	2	0.0	0.0	1.0	0.0	0.0	2	0.5	NG
TDS	mg/l	48.5	60.5	148	108.5	99.5	47.6	47.6	148	85.4	1000

NG = No Guideline

The result obtained from the analysis of chemical and biological parameters of groundwater samples from the study area is shown in Table 3. The Table shows the following minimum, maximum and mean values respectively, for the measured parameters; Ca (0.8, 1.8 and 1.1mgll), Mg (0.29, 0.58 and O.4mgll), S04 (0, 8 and 3.2mgll), N03 (0, 6.1 and 4.2), CI (6, 10 and 7.8mgll), Faecal coliform (0, 19 and 8.8CFU/100).

Figure 4 shows that Ca is highest around Akim and Ikot Effanga and lowest around Bacoco. Bacoco has the lowest population figure in the study area, therefore high Ca content in other areas of higher population value indicates that population contributes to the addition of Ca in groundwater in the area of study. Figure 5 shows a similar concentration of Mg in the area. Figure 6 shows a higher concentration of S04 around Ediba and Ikot Omin, while Akim, Essien Town and Bacoco have lower concentration of the parameter. This indicates that population density does not have any significant influence on the concentration of S04 in groundwater in the area. Figure 7 shows the concentration of Cl in groundwater in the area, the figure reveals that the area has similar concentrations of Cl, indicating that population do not show any noticeable influence on Cl concentration in groundwater in the area at present.

Table 3. Chemical and biological parameters

Parameter	Unit	W1	W2	W3	W4	W5	W6	Min	Max	Mean	WHO
Ca	mg/l	1.6	0.8	0.8	0.8	1.6	0.8	0.8	1.6	1.1	50
Mg	mg/l	0.56	0.29	0.29	0.29	0.58	0.29	0.29	0.58	0.4	100
SO_4	mg/l	0	8.0	1.0	8.0	1.0	1.0	0.0	8.0	3.2	200
NO_3	mg/l	4.5	3.2	6.1	5.9	5.6	0.0	0.0	6.1	4.2	45
Cl	mg/l	8.5	7.5	6.5	8.0	6.0	10.0	6.0	10.0	7.8	250
Fe	mg/l	0.0	0.0	0.0	0.0	0.0	0.0	-	-	-	0.3
Fecal Coliform	CFU/100	0.0	1.7	19	19	13	0.0	0	19	8.8	0

6. Distribution Pattern of Chemical Parameters in Groundwater Samples from the Area.

Figures 8-12 shows the distribution pattern of the measured parameters in groundwater samples from the study area. Figure 8 shows that Ca has the highest concentration around Akim and Ikot Effanga, and lowest concentration around Essien Town and Bacoco. Fig. 9 shows that Mg is highest around Akim and lkot Effanga with lowest concentration around Ikot Effanga and Bacoco. Figure 10 shows that S04 is highest around Ikot Omin and Ediba but lowest around Akim, Essien Town and Bacoco. Figure 11 shows higher concentration of $N0_3$around Essien Town, Ikot Omin and Ikot Effanga but lower concentration around Bacoco, Figure 12 shows that the highest concentration of CI occur around Bacoco and the lowest concentration occur around Ikot Effanga and Essien Town. This pattern of distribution does not show any clear relationship between population density and water chemistry.

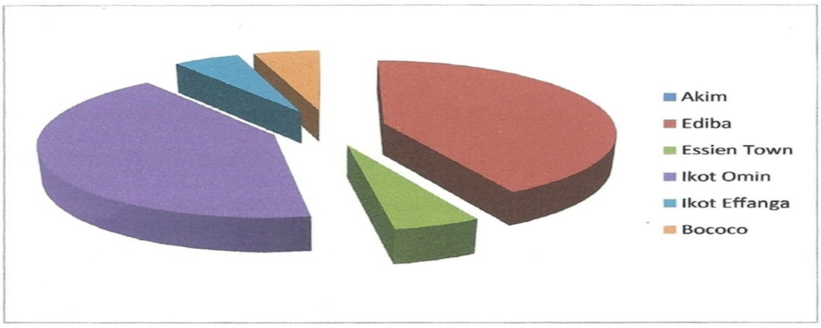


FIG.6: Pie chart comparing the concentration of SO_4 in the area.

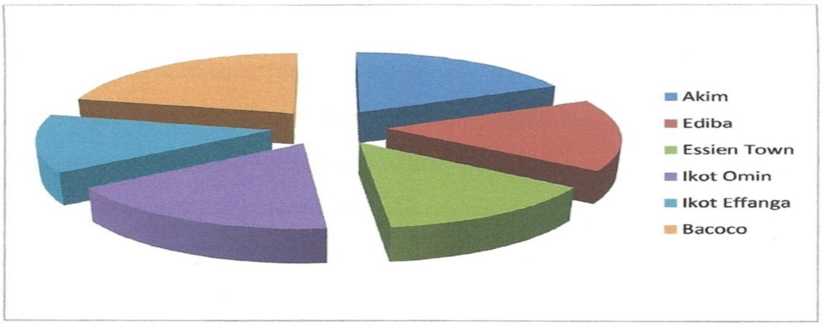


FIG.7: Pie chat showing the concentration of Cl in the area

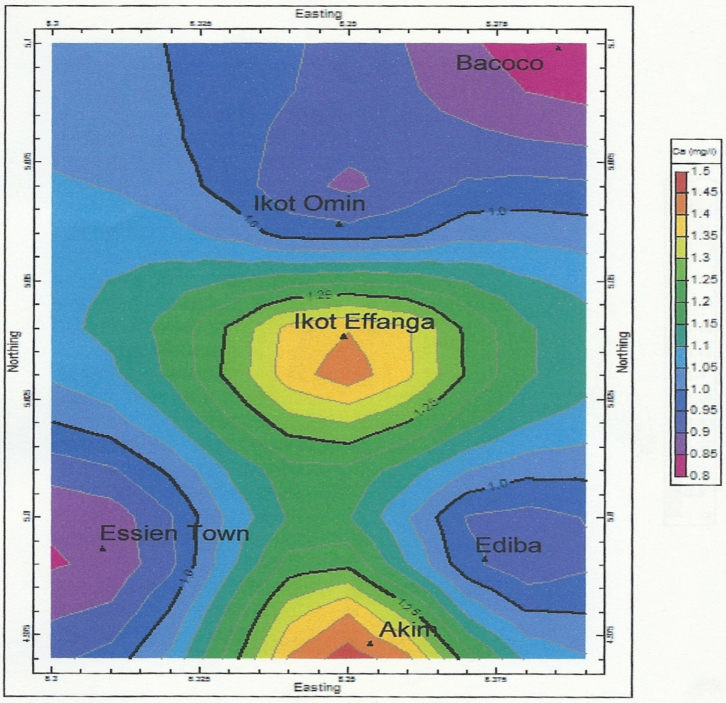


FIG.8 Distribution Pattern of Ca in the area

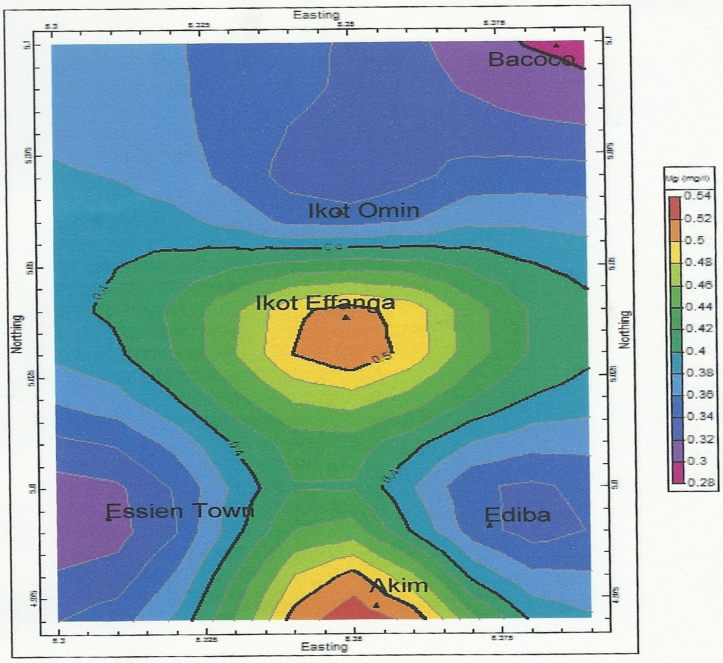


FIG.9: Distribution pattern of Mg in the area

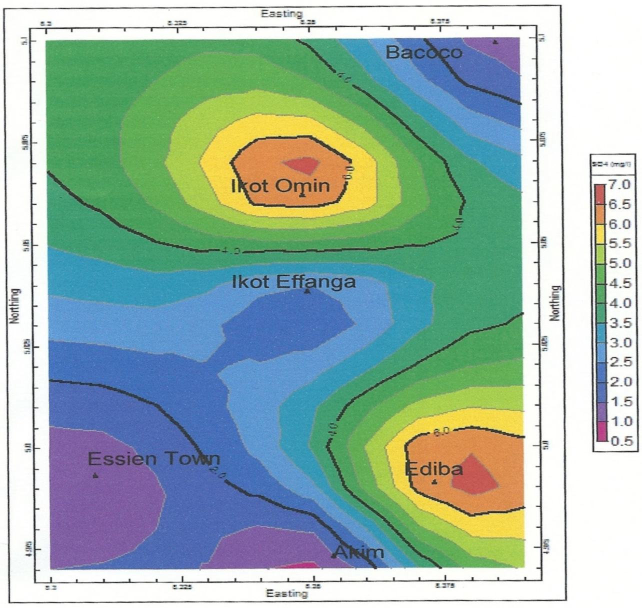


FIG. 10: Distribution Pattern of SO_4 in the area

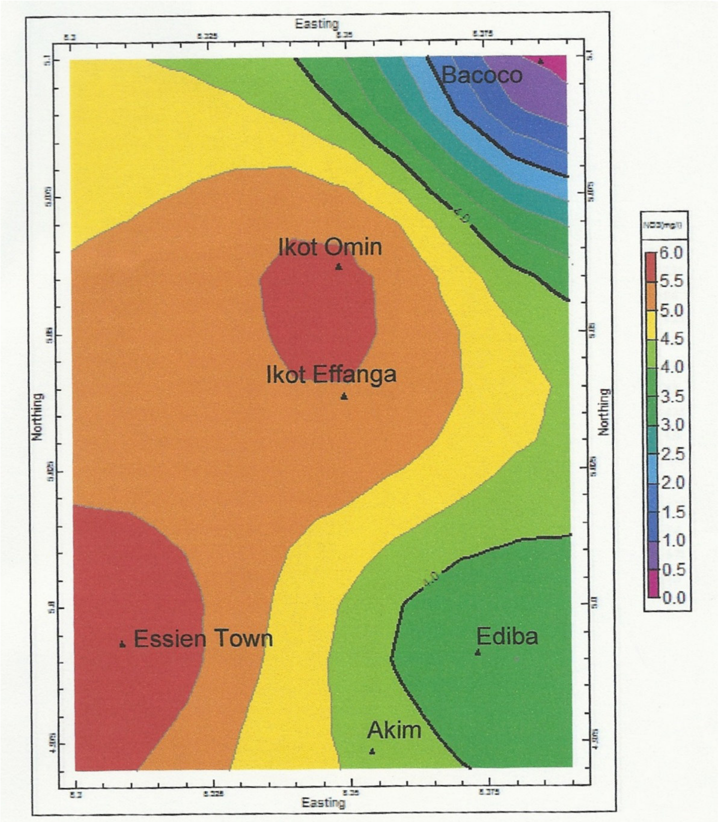


FIG.11: Distribution Pattern of NO_3 in the area

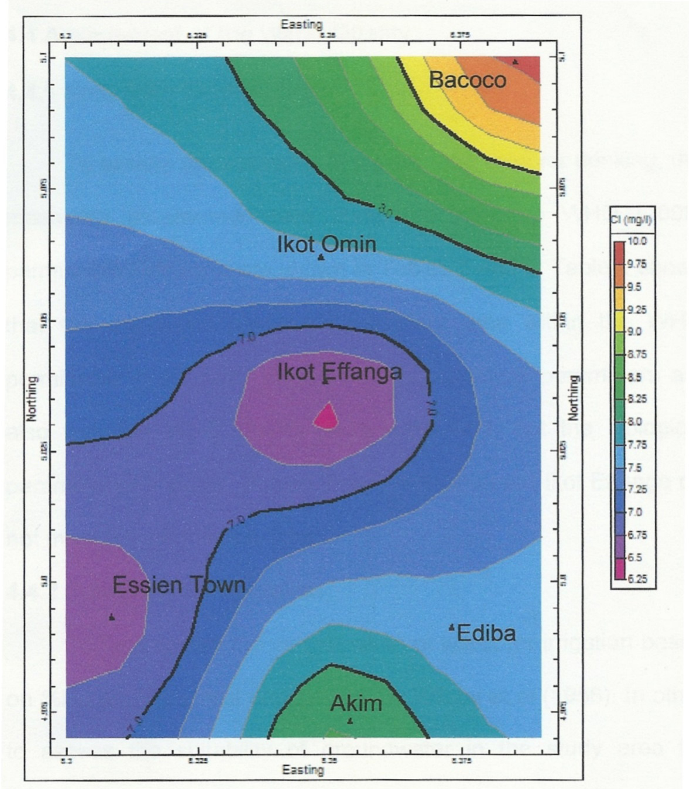


FIG.12: Distribution Pattern of Cl in the area.

7. Assessment of the Water Quality

7.1 *Suitability for Drinking*

To assess the suitability of water in the area for drinking, the measured parameters were compared with the WHO (2008) permissible limits and are shown in Tables 2 and 3. Table 2 shows that the measured physical parameters area within the WHO permissible limits and shows that the chemical parameters are also within the WHO (2008) permissible limit, but the biological parameters for Ediba, Essien Town, Ikot Omin and Ikot Effanga do not meet this permissible limit.

7.2 *Suitability for Irrigation*

Table 4 shows the classification of water for irrigation based on %Na and Electrical conductivity by Wilcox et al (1956). In order to assess the suitability of groundwater in the study area for irrigation purpose, the electrical conductivity was compared with those of Wilcox et al (1956). From the result, shown in Table 2, the electrical conductivity of groundwater in the area varies between 95.2 and 296j.JS/cm. this shows that groundwater in the area is excellent for irrigation except those around Essient Town (W3) that are good for irrigation.

Table 4: Quality Classification of water for irrigation (Wilcox et al, 1956)

Water Class	% Na (Meq/l)	Conductance
Excellent	<20	<250
Good	20-40	250-750
Permissible	40-60	750-2000
Double	60-80	2000-3000
Unsuitable	>80	>3000

8. Recommendations

- Groundwater around Ediba, Essien Town, Ikot Om in and Ikot Effanga should be treated before drinking.
- Further studies should include comparison of water chemistry with various population figures for different years

9. Conclusion

The study was carried out with the aim of assessing the influence of population density on groundwater quality in the area. The physic-chemical analysis shows the following range and mean value; temperature ranges between 28.5 30°C with a mean value of 29.5°C, pH ranges between 6.0 and 6.3 with a mean value of 6.05, indicating that groundwater in the area is slightly acidic, Electrical conductivity ranges between 95.2 and 296~S/cm with a mean value of 171.1JJ8/cm, Total dissolved solid varies between 47.6 and 148mg/1 with an average value of 85.4mg/l, Ca ranges between 0.8 and1.8 with a mean value of 1.1mg/l, Mg ranges between 0.29 and 0.58 with a mean value of O.4mg/l, 80_4 ranges between 0 and 8 with a mean value of 3.2mg/l, $N0_3$ ranges between 0, and 6.1 with a mean value of 4.2mg/l, Cl ranges between 6 and 10 with a mean value of 7.8mg/l and Faecal coliform ranges between 0 and 19 with a mean value of 8.8CFU/100.

The distribution pattern of the chemical parameters does not show a clear relationship between population density and water chemistry. Finally, assessment of the water quality shows that groundwater around in the study area is suitable for irrigation while groundwater around Ediba, Essien Town, Ikot Omin and Ikot Effanga is not fit for drinking, due to high content of coliform bacteria.

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